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Derivation of Regional, Non-breeding Duck Population Abundance Objectives to Inform Conservation Planning

Kathy K. Fleming
U.S. Fish and Wildlife Service, Division of Migratory Bird Management

Michael G. Brasher
Ducks Unlimited, Inc., Gulf Coast Joint Venture

Dale D. Humburg
Ducks Unlimited, Inc.

Mark J. Petrie
Ducks Unlimited, Inc., Pacific Coast Joint Venture

Gregory J. Soulliere
U. S. Fish and Wildlife Service, Upper Mississippi River and Great Lakes Region Joint Venture

ABSTRACT

During the early 2000s, M. Koneff (U.S. Fish and Wildlife Service) developed a methodology to derive regional non-breeding waterfowl population abundance objectives from continental abundance estimates. This information has been foundational to Joint Venture (JV) planning and implementation of habitat conservation for non-breeding waterfowl, especially wintering ducks. The 2012 NAWMP Revision and its amended population objectives motivated many JVs to begin updating their waterfowl implementation plans. Accordingly, interest grew in revisiting Koneff's analysis to calculate JV regional non-breeding population abundance objectives consistent with the revised NAWMP breeding objectives, while also seeking process refinement and repeatability using persistent datasets. We describe the data, equations, and caveats of the original derivation technique and compare results of alternative approaches using updated population and harvest information. Of the four methods compared, the superior approach (fewest number of short-comings) employed harvest data partitioned into separate autumn and mid-winter time periods, thus enabling finer temporal characterization of duck distribution and resulting population objective across individual JV regions. This approach made use of the least biased and most geographically consistent datasets, collected over an extended time frame, and likely to be collected in a similar manner into the future. JV regional population abundance objectives are provided for the 17 most commonly harvested duck species. Recommendations for applying results along with uncertainties, assumptions, and limitations which will guide future revisions are provided.

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INTRODUCTION

Regional population abundance objectives are foundational components for establishing waterfowl habitat objectives by Migratory Bird Joint Ventures (JVs). Petrie et al. (2011) described various methods used to calculate JV regional population abundance objectives for the non-breeding period, which are often more appropriately viewed as energetic carrying capacity targets (i.e., the amount of dietary energy required from waterfowl habitats to support waterfowl populations at desired levels over defined time frames during autumn–winter). The most common method for establishing population objectives for non-breeding waterfowl has involved state-level Mid-winter Waterfowl Survey (MWS) and county-level harvest data. These data are combined across the U.S. and then used to proportion or "step-down" continental waterfowl population objectives to each region based on MWS data and harvest distribution. Continental objectives for breeding waterfowl have been established in the North American Waterfowl Management Plan [NAWMP] using long-term estimates of waterfowl abundance in primary surveyed areas as well as un-surveyed areas (NAWMP Committee 2012; see Appendix A). Integrating estimates of seasonal mortality into these various datasets, regional scale abundance estimates were back-calculated to the mid-winter period. Typically, migration chronology data are then used to extrapolate the mid-winter objective across the non-breeding planning period to generate an estimate of duck-use-days (DUDs) and associated energy requirements, although other methods are also available for translating a mid-winter population objective into a habitat-objective (Petrie et al. 2011).

M. Koneff (U.S. Fish and Wildlife Service) was the first to provide a comprehensive collection of mid-winter population objectives based on a common method, and many JVs have based their non-breeding population and habitat objectives on these results. However, Koneff's analyses were applied to the original 1986 NAWMP population objectives and reflected winter waterfowl distributions (as indexed by the MWS) during the 1970s and 1990s. The 2012 NAWMP and its subsequent "Revised Objectives" addendum established new quantitative breeding population objectives for the Traditional and Eastern Survey Areas (NAWMP Committee 2014; see Appendix B). The 2012 NAWMP also compelled the waterfowl conservation community to critically examine how variation in population abundance is considered in conservation planning, by establishing dual objectives reflecting the long-term average (LTA; 1955–2014) and the upper 80th percentile of the LTA.

Waterfowl distributions of the 1970s and 1990s may no longer reflect contemporary distributions during the non-breeding period. Because many JVs are updating their implementation plans to address 2012 NAWMP recommendations, while also incorporating latest research and monitoring results, the NSST thought it timely to reexamine regional population abundance objectives. This work updates Koneff's original analysis using contemporary data, but also explores alternative methods and dataset combinations to establish regional population objectives for the non-breeding period. Our intent was to provide a common basis for "stepping down" revised continental population objectives to regional scales.

STEP-DOWN METHOD — THE BASICS

The original "step-down method" employed by Koneff used 1970–1979 and 1990–1999 state MWS totals of each waterfowl species to partition the continental (NAWMP) objective among states, and then used county-level harvest estimates to allocate (distribute) the state mid-winter totals among counties within a state. The general form of Koneff's equation is:

$$N_{ij} = \frac{p_{(\mathrm{mws})ij} \times p_{(\mathrm{h})ij} \times P_i}{0.85} \qquad \text{(Eq.1)}$$

where N_{ij} is the mid-winter population objective for species i allocated to county k of state j, $p_{(\mathrm{mws})_{ij}}$ is the proportion of the total mid-winter count of species i (U.S. + Mexico) in state j, $p_{(\mathrm{h})_{ij}}$ is the proportion of the state harvest of species i in county k of state j, and P_i is the continental objective for species i. The denominator 0.85 is used to back-calculate a mid-winter objective from the breeding population objective by assuming an 85% survival rate between mid-winter and the start of the breeding season. County totals were then aggregated to each Joint Venture region. We updated Koneff's analysis using this equation and three other methods plus recent MWS and harvest data and current continental population objectives.

EXPANDING NAWMP POPULATION OBJECTIVES TO THE CONTINENTAL SCALE

Revised population objectives of the 2012 NAWMP are specified in terms of long-term average populations of breeding ducks and the 80th percentile of the LTA for 12 common duck species or species groups (NAWMP Committee 2014). However, these revised NAWMP objectives were based only on estimates of breeding ducks in the Traditional Survey Area (TSA) and Eastern Survey Area (ESA) (Figure 1) and thus represent only a portion of the total continental breeding population. Consequently, stepping-down NAWMP objectives (i.e., from TSA and ESA only) to regional units for the non-breeding period would underestimate the number of birds an area should expect to support, and similarly the habitat needed to support them. Koneff recognized this and used approximations of total continental populations when deriving regional objectives for conservation planning during the non-breeding period. We followed Koneff's approach by calculating continental population sizes that would be expected when NAWMP breeding population objectives are achieved. We consider these to reflect "population abundance objectives at the continental scale," and we hereafter refer to them as "continental objectives." Our methods for calculating continental objectives varied among species, or groups of species, because of disparities in the quality and availability of species-specific population data.

For common TSA species including American green-winged teal, American wigeon, blue-winged teal, canvasback, gadwall, mallard, northern pintail, northern shoveler, redhead, and scaup (lesser and greater combined), we calculated continental objectives based on the relationship between estimated population abundance at the continental scale and the TSA. We used information presented in the 2012 NAWMP (NAWMP Committee 2012; Appendix A) to represent continental breeding duck population size from 2002–2011 for these species. To calculate continental objectives, we first determined the ratio between mean population size in the TSA and estimates of total continental population abundance during 2002–2011. We then applied this ratio to the species-specific revised NAWMP population objectives (NAWMP Committee 2014).

Our specific calculations were as follows:

$$Continental\ obj_i = \frac{NAWMP\ obj_i}{\left({N\_TSA_{i_{2002-11}}}\Big/{N\_Continental\ _{i_{2002-11}}} \right)}, \qquad \text{(Eq.2)}$$

where $NAWMP\ obj_i$ is the LTA or 80th percentile objective from the TSA for species i as provided in the 2012 NAWMP Addendum (NAWMP Committee 2014; Appendix B), $N\_TSA_{i_{2002-11}}$ is the mean population size from 2002–2011 of species i in the TSA as presented in the 2012 NAWMP (NAWMP Committee 2012; Appendix A), and $N\_Continental_{i_{2002-11}}$ is the continental population size for species i as presented in the 2012 NAWMP (Appendix A). We applied this calculation to both the LTA and 80th percentile objectives for each species, thus generating 2 sets of continental population objectives (i.e., long-term average and 80th percentile thereof).

The LTA and 80th percentile breeding population objectives from the Eastern Survey Area (ESA) were also calculated and presented alongside the revised NAWMP objectives for mallards and green-winged teal (NAWMP Committee 2014). However, we used only data from the TSA to calculate continental objectives for these species because the overwhelming majority breeds in the TSA. Relevant data and resulting continental objectives are presented in Table 1.

NAWMP revised objectives (NAWMP Committee 2014) for American black ducks, ring-necked ducks, and goldeneyes were based on data from only a portion of their breeding ranges, necessitating alternative methods for calculating continental objectives. Specifically, for American black ducks, we assumed that the combined areal coverage of the ESA breeding population survey and the Northeast Plot Survey would encompass essentially the entire continental breeding range of this species. Thus, we combined annual breeding population estimates from these surveys for 1998–2014 and calculated the LTA and 80th percentile to serve as our continental objectives for this species (Table 2). Similarly, for ring-necked ducks and Barrows and common goldeneyes, we assumed that the combined areal coverage of the TSA and ESA breeding population surveys encompassed the vast majority of the continental breeding range of these species. Thus, we combined annual breeding population estimates from these surveys for 1998–2014 and calculated a LTA and 80th percentile value to serve as our continental objectives for ring-necked ducks and goldeneyes (Table 2). Because survey data do not differentiate between common and Barrow's goldeneyes, we assumed common goldeneyes accounted for ~82% of the total goldeneye population (NAWMP Committee 2012; Appendix A). We chose 1998 (as opposed to 1990 in the 2012 NAWMP addendum) as the beginning date for our time series because that was the first year in which the current full extent of the ESA was surveyed.

For cinnamon teal, wood ducks, ruddy ducks, and all North American sea ducks (tribe Mergini) other than goldeneyes, we adopted recent (2002–2011) estimates of continental breeding population size as presented in the 2012 NAWMP (Appendix A) as the LTA continental objective. We based this decision on the fact that long-term population survey data are lacking for significant portions of these species' breeding ranges, which makes it difficult to reliably update population statistics (e.g., long-term averages). Additionally, for these species we did not calculate a continental objective reflecting an 80th percentile level because of these same data limitations, and because population sizes for many of these species appear to be declining. Simply maintaining populations at existing levels was viewed as a desirable, yet challenging, objective. Thus, in analyses that involved stepping-down 80th percentile objectives to JV regions, we used the LTA objectives for cinnamon teal, wood ducks, ruddy ducks, and all sea ducks (Table 3). A complete list of species-specific continental population objectives, as calculated by the methods described herein, is presented in Table 4.

ACCOUNTING FOR BIRDS WINTERING OUTSIDE THE U.S.

Some waterfowl winter largely outside the U.S. and are not recorded in the annual MWS. Similar to Koneff, we adjusted continental population objectives to account for ducks wintering in Mexico. For each of these species we calculated the average proportion of the total MWS counts (U.S. + Mexico) that occurred in the US, using only the 6 years when all or nearly all of the major waterfowl areas in Mexico were surveyed (1979, 1980, 1991, 1994, 1997, 2000) (Table 5). We multiplied these proportions by the proportion of each U.S. state's MWS estimates relative to the total U.S. MWS counts to adjust the stepped-down population objective accordingly: $p_{(\mathrm{mws})_{ij}}$ = ($MWS_{US}/MWS_{(US+Mex)}$) x (MWS_j /MWS_{US}).

Significant numbers of blue-winged and cinnamon teal migrate to areas in Central and South America that are not included in the MWS (Baldassarre 2014); therefore, we could not rely solely on MWS to calculate the number of blue-winged teal expected to winter in the U.S. Koneff's original method used actual mid-winter counts of blue-winged teal to derive a number to be allocated among JV regions during the mid-winter period, but reductions in the number of states conducting the MWS during recent years and uncertainty about detection rates during the MWS limited the utility of this approach. Instead, we assumed that only 25% of blue-winged teal remained in the U.S. by mid-October and that this decreased to 5% by mid-winter. While informed by virtually no empirical data, we believe this assumption is consistent with the conclusions of Baldassarre (2014:465) that, "…only a miniscule percentage of the blue-winged teal population winters in the United States."

Similarly, we lacked comprehensive datasets to estimate the number of cinnamon teal that remain in the U.S. during winter. For this species, we followed Koneff's approach of relying on assumptions of Bellrose (1976), who suggested that only 1% of cinnamon teal remain in the U.S. during winter. Thus, we determined a LTA mid-winter objective for cinnamon teal by first adjusting the continental breeding objective by the assumed 85% survival rate between mid-winter and the start of the breeding season, and then calculating a value equal to 1% of this number (i.e., [(300,000/0.85) × 0.01]). We assumed that 3 times as many cinnamon teal remained in the U.S. at mid-October than mid-winter. We used these same values in analyses that stepped-down 80th percentile objectives (Table 3).

MODIFICATIONS TO HARVEST AND MID-WINTER SURVEY DATA FOR BLUE-WINGED AND CINNAMON TEAL

To step down population objectives for blue-winged and cinnamon teal separately, it was necessary to partition their combined harvest data and MWS totals into approximate species proportions. However, this was problematic because these species are not distinguishable in mid-winter or harvest surveys. Thus, we calculated species proportions by county for harvest data, and by state for mid-winter data using auxiliary data. For the harvest data, we examined information from eBird (http://ebird.org/content/ebird/) checklists to estimate the ratio of blue-winged to cinnamon teal observed during the autumn and winter periods in each JV county where both species occur, and then we used this ratio to calculate the harvest totals of each species. For mid-winter data, we assumed that all “blue-winged/cinnamon teal” counted during the MWS were blue-winged teal except for California, where we used the proportion of blue-winged to cinnamon teal from eBird checklists for the January-February mid-winter period (0.17:0.83) to allocate the mid-winter totals.

ACCOUNTING FOR REDHEADS WINTERING IN THE U.S. GULF OF MEXICO

A major portion of the North American redhead population has historically wintered along the Texas coast (≥65%, Weller 1964). However, the Texas MWS is not ideally designed to estimate redhead abundance because of their tendency to exhibit clumped distributions within the Laguna Madre, an important area for this species. Similarly, redheads wintering in key offshore areas of Louisiana are not counted during the Louisiana MWS. Independent of the traditional MWS, the U.S. Fish and Wildlife Service conducted a Gulf Coast Redhead Survey from 1981–2012 to monitor distribution and trends of redheads in near-shore Gulf habitats from Cedar Key, Florida, to Tampico, Mexico (Fred Roetker, USFWS, unpublished data). The survey used a cruise method to enumerate total redheads within key geographic regions across the Gulf, although regions in Mexico were not surveyed every year due to various logistical concerns. From 1981–2012, based on the subset of years during which all regions were surveyed (i.e., 1991, 1994, 1997, 2000), the average number of redheads using the surveyed areas was 756,000. Hence, redhead concentrations in areas not covered by the MWS can be substantial, and failure to account for these could lead to regional population objectives for the non-breeding season that underestimate the continental importance of given geographies.

We augmented Texas and Louisiana MWS data with Gulf Coast Redhead Survey data for 1981-2003 and 2005-2012 for the purpose of 1) calculating the proportion of redheads wintering in the U.S. and 2) allocating winter population objectives among counties, for those methods that relied on MWS data (i.e., Methods 1 and 3). During years when Florida conducted its MWS, it was not necessary to supplement MWS data because redheads counted during the Gulf Coast Redhead Survey were already incorporated in Florida state mid-winter totals. However, during years when Florida did not conduct a MWS (i.e., post-2004), we used redhead counts from the Gulf survey to represent redhead distributions in Florida. Redheads enumerated in Mexico during the Gulf Coast Redhead Survey were already incorporated in Mexico MWS data. When calculating the proportion of redheads wintering outside the U.S., we used Gulf Coast Redhead Survey data from only those years when all regions were surveyed (i.e., 1991, 1994, 1997, 2000), among the six years previously chosen for calculating the proportion of ducks wintering outside the U.S.

METHODS FOR ALLOCATING CONTINENTAL POPULATION OBJECTIVES TO REGIONAL SCALES DURING THE NON-BREEDING PERIOD

Rather than simply updating Koneff's analysis, we explored alternative methods based on different assumptions about how the data represent the timing of waterfowl migration and distribution of wintering ducks. For all four methods described below, when a county was intersected by a JV regional boundary, the county harvest value was allocated to the intersecting JVs in proportion to the area of the county falling within each JV region. We ran each analysis using both the LTA and 80th percentile of revised continental population objectives for the 17 most commonly harvested duck species. Regional population objectives were not calculated for 13 duck species with relatively limited North American harvest or for any of the North American goose or swan species.

Method 1: This was identical to Koneff's original analysis, except we updated it by using current JV regional boundaries (Figure 2), 1999–2012 MWS data, 1999–2013 harvest data from the entire autumn–winter period (September 1–January 31), and revised continental breeding population objectives (Table 4).

Method 2: This analysis was identical to Method 1, except we used a subset of harvest data (December 11–January 20) to better align with the MWS period (i.e., early January). This resulted in a reduction in the number of counties with harvest data due to the shorter time period and closed hunting season in some areas. For each species, we summed county-level harvest during this time period across all years, and calculated the proportion of total harvest in each county. We then used Koneff's formula (Eq. 1) to estimate a non-breeding population objective in each county, and aggregated these to the JV regional scale.

Method 3: This analysis was similar to Method 1, except we used only harvest data (1999–2013) to allocate winter population objectives (i.e., MWS data were not used in this method). We used the entire harvest period (September 1–January 31) to represent the complete migration and winter period. For each species we summed county-level harvest across years and then calculated the proportion of total U.S. harvest in each county. We used the general form of Koneff's equation (Eq. 1), but removed the mid-winter survey parameter to estimate the non-breeding population objective in each county, and aggregated these to the JV regional scale.

Because we used data from the entire harvest period to represent waterfowl distribution, we chose the approximate mid-point of that period as the temporal point of reference for the resulting population objectives. Although the total harvest period spanned September 1–January 31, we based our midpoint (November 29) on the period September 25–January 31, because prior to this date only early teal seasons and regular duck seasons in a few minor harvest states were open, all of which were of limited utility for informing spatial distribution of the majority of waterfowl species across the lower 48 states.

Use of a different temporal point of reference (November 29) required calculating unique continental population objectives for that date, and those objectives would necessarily be larger than those calculated for a mid-winter point of reference (i.e., fewer ducks would be alive during early January than late November due to various mortality factors). Methods 1 and 2, in following the original procedures used by Koneff, assumed 85% survival between mid-winter and the period during which the May breeding population survey is conducted (i.e., the approximate start of the breeding season), whereas Method 4 (see below) assumed 70% survival between the point of reference for the autumn period (October 28) and the breeding season. For the temporal point of reference used in Method 3 (November 29) we assumed survival rate was constant between the autumn and mid-winter periods (see Method 4), and therefore calculated a pro-rated survival rate from November 29 to the breeding season of 0.77. Additionally, this method assumed essentially all birds that were going to migrate to Mexico had done so by November 29; therefore, the correction for number of birds wintering outside the U.S. was applied.

Method 4: This analysis was similar to Method 3, in that it used only county-level harvest data to represent spatial distribution of ducks, but we subsetted harvest data into autumn (i.e., autumn-early winter) and mid-winter periods in an attempt to capture temporal differences in the spatial distribution of ducks during the non-breeding season. Because spatial distributions were inferred from county-level harvest data and hunting season dates differ regionally (with the greatest differences occurring between northern and southern latitude states), thoughtful selection of the starting and ending dates for each period was important to minimize potential bias. Thus, we used data on hunting season dates across the U.S. to identify the time periods during which the majority of hunting zones were open, separately for the autumn and mid-winter periods (Figure 3). We initially selected October 9 and November 30 as the starting and ending dates for the autumn period (Method 4a), and December 1 and January 22 as the starting and ending dates for the mid-winter period (Method 4c). This resulted in each period spanning 53 days. However, we evaluated the effect of our choice for season start date by conducting separate analyses where the start and end dates captured the entire harvest period (i.e., September 1–November 30 for the autumn period [Method 4b] and December 1–January 31 for the mid-winter period [Method 4d]). For these methods, we chose October 28 and January 1 as the temporal points of reference (i.e., mid-points) for our autumn and mid-winter seasons, respectively.

Partitioning the non-breeding season into two discrete periods required calculating unique population objectives for each period. As in Method 3, the number of birds to be allocated among JV regions during the autumn period should necessarily be larger than the number to be allocated during the mid-winter period considering timing of emigration from the U.S. (teal) and late autumn–winter mortality. We assumed that only 25% of blue-winged teal remained in the U.S. by mid-October and that this decreased to 5% by mid-winter. While informed by virtually no empirical data, we believe this assumption is consistent with the conclusions of Baldassarre

(2014:465) that, "…only a miniscule percentage of the blue-winged teal population winters in the United States." For all other species, we assumed that few birds had yet migrated out of the U.S. by the mid-point of the early period, and we thus removed the adjustment for birds wintering in Mexico. We then divided this number by 0.70 under the assumption of an average 70% survival rate between mid-October and the subsequent breeding season. As in Methods 1 and 2, we assumed an 85% survival rate between mid-winter and the subsequent breeding season.

Mid-winter Population Objectives for Mexico: We also calculated mid-winter population objectives for Mexico, corresponding to the long-term average and 80th percentile of the long-term average continental breeding population objectives, for 13 species or species groups (Table 10). As we did for Methods 1, 2, and 4, we assumed an 85% mortality rate between mid-winter and the subsequent breeding season. We assumed 70% of blue-winged teal and 95% of cinnamon teal winter in Mexico at mid-winter. For all other species or species groups, we used data from the Mid-winter Waterfowl Survey to estimate the percentage of each species or species group that is expected to winter in Mexico (Table 5). We did not calculate population objectives for Mexico for the autumn time period as defined in Method 4.

RESULTS

Resulting JV population abundance objectives varied among methods, such that overall total duck objectives for some JVs differed 5-fold. Methods that incorporated MWS data tended to produce larger objectives for JVs with more rigorous MWS effort (e.g., GCJV, LMVJV, OPJV). Further, the choice of start and end dates for defining the autumn and mid-winter periods, and the associated selection of harvest data, impacted results to an appreciable degree. Thus, we considered a variety of factors when identifying a recommended method. While a check of "apparent reasonableness" of results based on comparison to existing population objectives was considered useful, we believed it was more important to base a recommendation on the merits and shortcomings of each method largely independent of the numerical results and how they compared to existing objectives. Specifically, in consultation with additional members of the NSST, we considered the following traits to be important when comparing methods: 1) data are minimally biased, or at least consistently biased across space and time; 2) data are of sufficient precision to impart confidence in the results; 3) data are consistently available across the entire area and time period of interest; 4) data are available in a time series of sufficient length to overcome, or permit characterization of, variability in the system; and 5) data are likely to be available in a similar or comparable form into the future to enable repeatable analyses.

While each method and their underlying datasets fell short of these idealized traits, some methods had greater shortcomings. In particular, methods that relied on MWS data were considered unfavorable options because of deficiencies in the dataset. For example, MWS methodologies differ markedly through time and among states, these surveys have been discontinued in some states, and it is considered likely that MWSs will be discontinued in additional states going forward. This effectively eliminated Methods 1 and 2 from consideration. Method 3 did not incorporate MWS data, but it was considered problematic because it used the entire autumn–winter harvest record as an index to duck distribution, and thus, regional population objectives. Regional population abundance objectives essentially serve as an approximation of the number of ducks likely to occur for a relatively short period of time (e.g., <7 day period) during the autumn–winter period. We found it difficult to justify selection of a relatively short period of time to which population objectives from Method 3 should be assigned, because it reflected the underlying distribution of harvest over the entire autumn–winter period.

Method 4 did not rely on MWS data, and although it used the entire harvest period, these data were partitioned into separate autumn and mid-winter time periods, thus enabling finer temporal characterization of duck harvest distribution and resulting population objectives. Within Method 4, the more inclusive start and end dates of the harvest record (Methods 4b and 4d) were favored to capture patterns of harvest and duck distribution at extreme northern and southern latitudes that may have been overlooked if we used the truncated data (Methods 4a and 4c). Overall, Methods 4b and 4d were believed to make use of the least biased and most geographically consistent datasets, collected over an extended time frame, and likely to be collected in a similar manner into the future. Thus, the NSST recommends Methods 4b and 4d as the basis for regional population objectives for the autumn and mid-winter periods (Tables 6–9).

The total duck objective across all JVs in the U.S. during the autumn period (Method 4b) was 69,549,032, while that for the mid-winter period (Method 4d) was 52,767,891. This difference is attributable to the approximate 15% mortality rate between late October and early January, as well as the migration of ducks into Mexico, as modeled in our analyses. Total mid-winter objectives for Mexico, for the 13 species or species groups for which we had reasonable data, was 9,326,940 for the LTA and 11,952,287 for the 80th percentile of the LTA (Table 10).

Spatial datasets depicting county-level results from Methods 4b and 4d, for both the LTA and 80th percentile population objectives, can be downloaded from the following link: https://www.fws.gov/migratorybirds/pdf/management/NAWMP/FlemingOutputFiles2017.zip.

DISCUSSION

Comparison to Earlier Results

Previous non-breeding population abundance objectives for most JVs were based on methods incorporating MWS data (Petrie et al. 2011). Except for using MWS data to account for ducks wintering in Mexico, our recommended method (4b and d) relies exclusively on harvest data to apportion continental objectives among JV regions. This is a significant departure from previous methods and the alternative approaches we assessed in this document. Comparing our results to those from earlier efforts is instructive for understanding the potential implications of this new method for JV conservation planning. For these comparisons we focused on the results of Koneff, the only prior effort to derive regional non-breeding population abundance objectives using a consistent methodology.

Koneff produced regional population abundance objectives for only the mid-winter period; thus, comparisons between his results and ours were limited to the mid-winter period (Method 4d), and using only a subset of species that were common across both analyses (i.e., mallard, northern pintail, American black duck, gadwall, American wigeon, green-winged teal, blue-winged teal, cinnamon teal, northern shoveler, wood duck, canvasback, redhead, scaup, ring-necked duck, ruddy duck). Based on Koneff's analysis using 1990's MWS and harvest data, the total objective for these species at mid-winter in the U.S. was 49,628,583. By comparison, the total objective for these species in the U.S. under Method 4d, as stepped-down from LTA continental objectives, was 49,246,765.

Although predicted total duck abundance at mid-winter in the U.S. was similar between these methods, appreciable differences occurred for some species. U.S. mid-winter objectives for some species were greater for Method 4d than Koneff's analysis, including gadwall (+ 23%), redhead (+ 34%), northern shoveler (+ 65%), ring-necked duck (+ 69%), and ruddy duck (+100%). For other species, total U.S. mid-winter objectives from Method 4d were lower than those from Koneff, including American wigeon (− 15%), scaup (− 19%), northern pintail (− 28%), and American black duck (− 31%). In some cases, differences were even greater at the level of individual JVs. Closer examination revealed that some of these disparities were explained by adjustments to NAWMP continental objectives since Koneff's analyses. For example, the northern pintail mid-winter population objective in the Central Valley JV from Koneff's 1990 analysis was 2,480,719, but was 1,613,310 as calculated from Method 4d (based on the LTA objective), representing a 35% reduction in regional population objective. Koneff used a continental population objective for northern pintail of 6,999,500, whereas our objective was 5,111,939 (i.e., 27% lower than Koneff's objective). Other factors, including changes in methodology as well as actual shifts in duck distribution, likely also contributed to disparities in population objectives between our methods and previous efforts.

Application of Results

Regional population abundance objectives serve as an approximation of the number of birds expected to occur in a JV region at a given point in time during the non-breeding period. In contrast to previous methods that generated objectives specific only to the mid-winter period, our recommended method yields population objectives for two distinct periods during autumn–winter. Petrie et al. (2011) recognized that stepped-down mid-winter objectives were of limited utility for some northern latitude JVs, because few birds remain in those locales at mid-winter, making it difficult to reliably extrapolate across the larger planning period. Thus, our recommended method provides a potential improvement over previous methods by giving JVs the option of using either the autumn or mid-winter objective as the basis for calculating total expected bird use-days. We expect JVs at northern latitudes to find greater utility in the autumn objective (Method 4b) and JVs at southern latitudes to find greater value in the mid-winter objective (Method 4d), as these time periods generally align with peak duck abundance in their respective landscapes. The choice for mid-latitude JVs may not be as clear and will likely depend on knowledge of region-specific migration chronology. In some cases, it may be possible to use both the autumn and mid-winter objective to calculate or refine duck use-day objectives for the entire autumn–winter period, although we anticipate this to be unnecessary if a complete record of migration chronology is available.

Regional population objectives by themselves do not account for temporal variation in waterfowl abundance across autumn–winter, and thus must be combined with additional data to calculate overall duck use-day objectives. Petrie et al. (2011) recommended a process by which population objectives can be combined with migration chronology data to calculate expected duck use-days across the autumn–winter–spring planning period. Species-specific migration chronology can be assessed from a variety of data sources including eBird (http://ebird.org/content/ebird/), the USFWS Integrated Waterbird Management and Monitoring Program (http://iwmmprogram.org/), and other systematic monitoring programs (e.g., Soulliere at al. 2013). Important in this process is selecting the date to which regional population abundance objectives are assigned, after which migration chronologies are used to extrapolate duck abundance estimates for weekly or bi-weekly periods throughout the remainder of the non-breeding planning period relative to the selected date (see Soulliere at al. 2013). All previous efforts used roughly January 1 (i.e., mid-winter) as the date to which the calculated population objectives were assigned. Our recommended method generated both an autumn and mid-winter population objective, which required identifying a temporal point of reference for each period. Specifically, we recommend using the mid-point of the period over which each objective was calculated (i.e., Oct 28 and Jan 1 for the autumn and mid-winter objectives, respectively) as the temporal points of reference. We acknowledge that species-specific migration timing and temporal patterns of harvest may be skewed away from the mid-points for some regions and/or species. Thus, where sufficient evidence exists to justify it, individual JVs may deem it appropriate to select alternative temporal points of reference to better align with patterns of duck abundance in their geography. We urge JVs to clearly document the process and outcome of alternative methods used to adjust regional objectives.

Consistent with the 2012 NAWMP, we calculated continental and regional population abundance objectives reflecting duck abundance at both long-term average and 80^{th} percentile of long-term average levels. However, because it was beyond the initial scope of our task, at this time we are unable to offer specific guidance on the appropriate interpretation or use of these dual objectives. Clearly, there is a pressing need for such guidance. We believe the NSST is ideally positioned to facilitate this effort, and we recommend this be elevated as a high priority in the immediate future. Finally, we provide JV regional abundance objectives for only the most commonly harvested duck species (Tables 6-9). Where other harvested species are a JV conservation focus, a similar approach (e.g., harvest in JV region / total U.S. harvest x continental abundance objective/estimate) may be used to generate regional non-breeding period objectives. Population monitoring data and expert opinion may be required to complete this process for non-harvest species (e.g., swans in most states)

Uncertainties, Assumptions, and Opportunities for Future Improvement

We calculated regional population abundance objectives for all U.S. Joint Ventures using a consistent and repeatable methodology with data that were uniformly available across all U.S.

regions of interest. Thus, we believe these results provide objectively-derived, useful targets for regional duck abundance during autumn and winter, and offer an important opportunity for JVs to use commonly derived objectives as the basis for habitat conservation planning during the non-breeding period. However, we recognize that some JVs may find it necessary to use locally-derived data and expert opinion to refine or supplement their respective population objectives. In these cases, we recommend JVs include in their implementation plans a clear justification and description of modifications made to these objectives, or alternative methods used to derive them (e.g., Petrie et al. 2011). If such modifications lead to substantial changes in population objectives for certain species, it is advisable to coordinate such changes with the other JVs that are particularly important for those species to ensure adequate habitat resources are provided in the aggregate.

Although highly useful in the context of conservation planning, our recommended method and accompanying datasets do not account for the full complement of factors governing the distribution and abundance of ducks throughout the autumn–winter period nor for the conservation planning necessary to guide specific management. These shortcomings should not detract from the utility of these results, but rather should be viewed as opportunities for future refinement. Although not exhaustive, the following is a list of notable uncertainties and assumptions within these analyses:

1) Distribution of harvest was assumed to be a reliable index of the distribution of ducks during autumn–winter. Opportunities to test this assumption may be possible at state or regional scales where rigorous surveys of waterfowl abundance across the autumn–winter period have been collected over a number of years (e.g., Missouri, Illinois).
2) The temporal points of reference for both the autumn and mid-winter periods were largely selected arbitrarily and assume that the spatial distribution of ducks at the mid-point of each period is similar to the proportional distribution of harvest as measured across the entire autumn or mid-winter period. In effect, this assumes the majority of harvest, and thus our index of duck abundance across space, is centered around the mid-point of each period, or rather that the temporal distribution of harvest is uniform within the autumn or mid-winter periods. The ramifications of this assumption deserve greater scrutiny, which may be accomplished by comparing temporal distribution of harvest and migration chronology at regional scales.
3) Assumptions about mortality rates between the start of the breeding season and the temporal points of reference for autumn and mid-winter periods were based on loose generalizations from a limited set of scientific studies, most of which were based on mallards only. The implications of applying an identical mortality rate across all species, which differ in life history traits and mortality risk factors, are unknown.
4) This method did not yield independent objectives for spring migration periods. For JVs that support ducks continuously through winter and spring, the lack of independent spring population objectives is of no consequence as migration chronologies can be combined with mid-winter population objectives to estimate duck use-days into the spring. JVs hosting birds primarily during migration periods and without a continuous record of duck abundance through spring have the greatest challenge in predicting

duck use days. Petrie et al. (2011) explored in more detail the challenges of developing population objectives for the spring period, and we provide only suggestions for assessing migration chronology to address these challenges.

5) Our recommended method used only U.S. harvest data, which effectively assumes all ducks planning to migrate out of Canada have done so by the mid-point of the autumn period (i.e., October 28). While this assumption is likely true for most duck species, at least in some years, appreciable numbers of ducks for some species may remain in Canada as of this date. Failing to account for birds still residing in Canada on this date, would lead to overestimates of duck population objectives and consequent habitat objectives for JVs in the U.S. Additional attention may be needed to assess the implications of this assumption, consider opportunities to refine it, and identify the species for which it would be most important to refine.
6) An important implication of using only U.S. harvest data was the inability to calculate non-breeding population abundance objectives for Canadian JVs. Although Canadian JVs are primarily focused on habitat conservation efforts to benefit waterfowl during the breeding season, some have invested in conservation planning efforts on behalf of waterfowl during the non-breeding period. Adapting our recommended method to enable calculation of non-breeding population objectives for Canadian JVs that need them (e.g., Pacific Birds Habitat JV, Eastern Habitat JV) will be a high priority going forward. We are actively investigating the utility of Canadian harvest data in this regard and will seek a solution to this issue in the immediate future, at which time the objectives presented herein will be updated as deemed necessary.
7) We did not include geese, swans, and many sea duck species in this analysis, primarily because revised NAWMP objectives for them have not yet been established, but also because of limited data for some species. This is an important need, and we recommend the NSST work closely with the NAWMP Interim Integration Committee, Flyway technical committees, and Sea Duck Joint Venture to address this.
8) We lacked empirical data on blue-winged and cinnamon teal migration chronology and distribution outside the U.S. during autumn and winter. Consequently, we used arbitrary assumptions about the percentage of their populations expected to remain in the U.S. and how these percentages change from autumn to mid-winter. With some exceptions (e.g., Gulf Coast JV), blue-winged and cinnamon teal population objectives, and thus our assumptions about migration chronology and distribution outside the U.S., likely have a relatively small influence on JV habitat objectives. Nevertheless, efforts to refine these assumptions would be useful, especially for JVs where these species may be abundant during autumn and winter.
9) We calculated mid-winter population objectives for Mexico, but we did not apportion these to finer spatial scales, although this could easily be done with supplemental data describing relative distribution of waterfowl among regions within Mexico.

CONCLUSIONS

Approximately 15 years have transpired since Koneff provided the first consistent calculation of regional population abundance objectives for JVs during the non-breeding period. We updated Koneff's analysis using alternative methods and calculated regional population objectives to be consistent with revised objectives of the 2012 NAWMP (NAWMP Committee 2014). This provides a unique opportunity for JVs to adopt population objectives based on an identical method, thus increasing the continuity of JV conservation planning for waterfowl during the non-breeding period. We recommend JVs adopt objectives as calculated from Methods 4b and 4d described herein. Should modifications to these objectives be deemed necessary by individual JVs, the rationale and methods used should be clearly described in their implementation plans. Going forward, we believe the NSST should provide guidance on how to interpret and incorporate the dual objectives of the 2012 NAWMP into regional-scale conservation planning models. Further, with support of the NAWMP Committee, we recommend the NSST assume responsibility for encouraging the adoption of these objectives, testing and improving upon the key assumptions in the analyses, and identifying the appropriate timeframe for updating objectives in the future.

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